<u>AMENDMENTS TO THE SPECIFICATION</u>

Please add the following new paragraph at page 1, before the heading "<u>BACKGROUND OF THE INVENTION</u>":

This is a Rule 1.53(b) Divisional Application of Serial No. 09/598,972, filed June 22, 2000, which is now allowed.

Please replace the paragraph at page 1, line 10, with the following rewritten paragraph:

Recently, it is proposed to correct tilt in an optical head in an optical disk drive with a liquid crystal element in order to correct aberration (Japanese Patent laid open Publications 10-79135/1998 and 11-3531/1999). The tilt is <u>an</u> inclination of <u>the</u> optical axis of <u>an</u> optical head relative to an optical disk. Electrodes in the liquid crystal element are provided as a plurality of divided areas of predetermined shapes, and voltages applied to the areas are controlled for tilt correction by changing <u>the</u> phase difference of a transmitting laser beam. Spherical aberration of object lens is a problem for higher density recording of optical disk when a short wavelength laser is used for a lens of high numerical aperture (NA). Spherical aberration is also corrected with the liquid crystal element.

Please replace the paragraph at page 3, line 5, with the following rewritten paragraph:

In a prior art optical head, a liquid crystal element is mounted not on an actuator which is a moving component, but on a fixed component. This is adopted in order to improve sensitivity on focusing and tracking by making the optical head compact and by using ~~the~~ <u>a light-weight</u> actuator ~~with a light weight~~. Tilt caused by inclination of the object lens in radial and tangential directions are corrected. However, when the object lens is moved in the radial direction, it is a problem that the optical axis of the object lens is shifted relative to the liquid crystal pattern, so that performance of aberration correction is deteriorated.

Please replace the paragraph at page 4, line 6, with the following rewritten paragraph:

In one aspect of the invention, in a liquid crystal driver, a periodic waveform generator generates a periodic waveform signal, ~~and~~ a phase shifter ~~which~~ receives the periodic waveform

signal from the periodic waveform generator and shifts phase thereof according to an instructed value, and an inverting element inverts an output signal of the phase shifter. A potential divider comprises a plurality of resistors connected in series, and the output signal of the phase shifter and the output signal of the inverting element are connected to two ends of the potential divider. A liquid crystal element comprises electrodes of a plurality of areas and a common electrode opposing the electrodes, wherein the common electrode is connected to the periodic waveform signal outputted by the periodic wave generator and the plurality of areas are connected to output voltages of the potential divider. Thus, tilt correction is performed with a simple structure of liquid crystal driver. When tilt is corrected in a plurality of directions, the liquid crystal driver may have a plurality of sets of the phase shifter, the inverting element and the potential divider for each direction.

Please replace the paragraph at page 5, line 11, with the following rewritten paragraph:

In a further aspect of the invention, an optical head comprises a light source, an object lens for converging a light beam emitted by the light source, and a liquid crystal element arranged between the light source and the object lens. The liquid crystal element comprises electrodes of a plurality of areas in a plane perpendicular to an optical axis of a light beam reflected from an optical disk and a common electrode opposing the electrodes via a liquid crystal layer. The electrodes ~~comprises~~ comprise a first electrode group used for correcting the light beam transmitting when no shift of the object lens occurs relative to the optical axis, an at least one second electrode provided adjacent to the first electrode groups in a first direction along which the object lens is shifted, and ~~an~~ at least one third electrode provided adjacent to the first electrode groups in a second direction opposite to the first direction.

Please replace the paragraph at page 8, line 24, with the following rewritten paragraph:

Figs. 24A, 24B and 24C are ~~diagram~~ diagrams of electrode patterns of liquid crystal elements;

Please replace the paragraph at page 9, line 4, with the following rewritten paragraph:

Figs. 26A and 26B are ~~diagram~~ diagrams of electrode patterns of liquid crystal elements.

Please replace the paragraph at page 9, line 8, with the following rewritten paragraph:

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, Fig. 1 shows a block diagram ~~on~~ of an electrical circuit of a liquid crystal driver according to a first embodiment of the invention. A periodic waveform generator 1 generates a periodic signal of a sine wave, square wave or the like. An amplitude controller 2 controls the amplitude of the waveform generated by the periodic waveform generator 1 to output a periodic signal V_{com}. A first phase shifter 3 shifts the phase of signal V_{com} from the amplitude controller 2 according to radial tilt instruction 5 to send signal V_{R+}, and a second phase shifter 4 shifts the phase of signal V_{com} from the amplitude controller 2 according to tangential tilt instruction 6 to send signal V_{T+}. The radial tilt instruction 5 designates an instructed value on radial tilt correction provided by a tilt servo device (not shown), and tangential tilt instruction 5 is an instructed value on tangential tilt correction provided by the tilt servo device. The phase shifters 3, 4 are, for example, delay elements for analog signals and shift registers for digital signals.

Please replace the paragraph at page 13, line 10, with the following rewritten paragraph:

In operation of the liquid crystal driver explained above, the electrode 13c is used commonly. In order to perform correction in the two directions independently of each other, the liquid crystal element 11 is driven so as to satisfy a condition of Vc = ~~Vg;~~ Vh, that is,

$$\{V_{R+} + V_{R-}\} / 2 = \{V_{T+} + V_{Tl}\} / 2 = V_c. \qquad (1)$$

Please replace the paragraph at page 14, line 5, with the following rewritten paragraph:

The values V_{R+}, $-V_{R-}$, V_{T+} and $-V_{T-}$ given by Eq. (2) satisfy Eq. (1) . Thus,

$$Vc = 0,$$

and (3)

$$\cancel{Vg}\ \underline{Vh} = 0.$$

Then, the region 14c in the liquid crystal element 11 is driven with a voltage of

$$Vc - V_{com} = - \sin (\omega t),$$

so that it is driven at an effective voltage irrespective of α and β. Therefore, ~~The~~ the effective voltage at the region 14c is constant when the radial tilt instruction 5 and the tangential tilt instruction 6 are given independently of each other.

Please replace the paragraph at page 14, line 18, with the following rewritten paragraph:

Next, tilt correction in radial direction is explained with reference Figs. 3 to 7. Fig. 3 shows signal waveforms of V_{com}, V_{R+} and V_{R-} when driven with a sine wave. In Fig. 3, V_{R+} is a waveform wherein phase is shifted relative to V_{com} by the instructed value α around the center position of θ = 90°. Fig. 3A shows waveforms for θ = 90° and α = 0°, Fig. 3B shows waveforms for θ = 90° and α = 45°, and Fig. 3C shows waveforms for θ = 90° and α = 90°.

Please replace the paragraph at page 16, line 3, with the following rewritten paragraph:

The effective voltage when the voltage patterns are applied is explained with reference to Fig. 5 which shows effective voltages applied to the regions 14a, 14b, 14c, 14d and 14e in the liquid crystal element when the instructed value α is changed between 90° and -90°. In Fig. 5, the regions 14a to 14e are arranged in the axis of abscissa, while the axis of ordinate represents normalized effective voltage. The effective voltage applied to the region 14c is constant ~~irrespectively~~ irrespective of the instructed value α. The effective voltages applied to the regions 14a and 14e are changed twice ~~than~~ compared to those applied to the regions 14b and 14d. The effective voltages applied to the regions 14a and 14b ~~is~~ are increased or decreased with the opposite sign to those

applied to the regions 14d and 14e. As will be understood from Fig. 5, the effective voltages can be increased or decreased according to the instructed value α like a seesaw having the center at the region 14c.

Please replace the paragraph at page 16, line 20, with the following rewritten paragraph:

Next, in the case of $\alpha = 45°$, radial tilt correction is explained with reference to Figs. 6 and 7. Fig. 6 shows a relationship between phase difference of transmitting light and the effective voltage applied to the liquid crystal element. In Fig. 6, axis of abscissa represents the effective voltage applied to the liquid crystal element, and axis of ordinate represents the phase difference of laser light transmitting the liquid crystal element. When the effective voltage is small, the liquid crystal is not excited, and the phase difference is small. As the effective voltage is increased, the phase difference tends to change linearly. As the effective voltage is increased further, the phase difference tends to increase gradually.

Please replace the paragraph at page 18, line 10, with the following rewritten paragraph:

It is noted that the amplitude controller 2 is not necessarily needed. If the operating point P in Fig. 5 is fixed, it can be included in the periodic waveform generator 1. Further, the amplitude controller 2 may be set at an input stage of the potential divider, and it ~~is~~ need not necessarily be arranged just after the periodic waveform generator 1.

Please replace the paragraph at page 18, line 24, with the following rewritten paragraph:

Further, as indicated with a dashed line in Fig. 1, an output terminal of output voltage Vc of the first potential divider 9 in correspondence to a half of the total resistance thereof is connected to another output terminal of output voltage Vh of the second potential divider 10 in correspondence to a half of the total resistance thereof. In this case the condition of Vc = Vh can be realized ~~at~~ with

high precision, and voltage difference between them can be prevented ~~to occur~~ from occurring when the characteristics of the potential dividers are different. Then, the electrode 13c is used commonly in the correction in radial and tangential directions, so that tilt correction can be carried out ~~at~~ with high precision without interference between the two directions, by satisfying the condition of Vc = Vh.

Please replace the paragraph at page 20, line 10, with the following rewritten paragraph:

Fig. 9 shows the phase difference of transmitting light when the effective voltages shown in Fig. 8 are applied. A solid line in Fig. 9 represents the phase difference of transmitting light in the liquid crystal when $VR_1 = VR_2 = 0$, while a dashed line in Fig. 9 represents the phase difference of transmitting light in the liquid crystal when $VR_1 = VR_2 = 2R$. Thus, it is apparent that the phase difference in radial direction can be changed by controlling the resistance values of VR_1 and VR_2 where the region 14c is at the center of the phase difference change. That is, this is equivalent to correction of spherical aberration of object lens.

Please replace the paragraph at page 21, line 14, with the following rewritten paragraph:

It is explained with reference to Figs. 10 and 11 that tilt correction can also be performed by using a square wave such as a digital waveform of TTL level, though the periodic signal generator 1 generates a sign wave in the cases explained above. Fig. 10 shows signal waveforms of V_{com}, V_{R+} and V_{R-} when driven with a square wave of duty ratio of about 50%. In Fig. 10, VR+ has a waveform shifted by the instructed value α with ~~for~~ $\theta = 90°$ at the center. Fig. 10A shows a signal waveform for $\theta = 90°$ and $\alpha = 0°$, Fig. 10B shows a signal waveform for $\theta = 90°$ and $\alpha = 45°$, and Fig. 10C shows a signal waveform for $\theta = 90°$ and $\alpha = 90°$.

$Vc = 5/2$ [V],

$V_{com} = 5/2 * (\mathrm{sign}(\sin(\omega t+\theta+\alpha)) + 1)$,

$V_{R+} = 5/2 * (\mathrm{sign}(\sin(\omega t+\theta+\alpha)) + 1)$, (5)

and

$V_{R-} = 5/2*(-\text{sign}(\sin(\omega t+\theta+\alpha)) + 1)$,

wherein sign(x) is 1 for $x > 0$, 0 for $x = 0$ and -1 for $x < 0$.

Please replace the paragraph at page 22, line 6, with the following rewritten paragraph:

A square wave is given by Eq. (5), and Fig. 10 is similar to Fig. 4 except that the sine wave is replaced with a square wave. The output voltage of the first potential divider 9 can be calculated similarly to Eq. (4) when $VR_1 = VR_2 = 6R$. Fig. 11 shows voltage patterns applied to the regions 14a, 14b, 14c, 14d and 14e.

Please replace the paragraph at page 22, line 12, with the following rewritten paragraph:

Figs. 11A, 11B and 11C show voltage patterns applied to the regions 14a, 14b, 14c, 14d and 14e when driven with a square wave, wherein the ordinate represents normalized voltage. Fig. 11A shows the voltage pattern for $\theta = 90°$ and $\alpha = 0°$, Fig. 11B shows the voltage pattern for $\theta = 90°$ and $\alpha = 45°$, and Fig. 11C shows the voltage pattern for $\theta = 90°$ and $\alpha = 90°$.

Please replace the paragraph at page 23, line 3, with the following rewritten paragraph:

The operation is explained above for both cases of sine wave and square wave outputted by the periodic signal generator 1. However, the waveform is not limited to the above two types, and any signal satisfying Eq. (1) may be used. When the periodic waveform generator outputs a sine wave, signals can be processed in an analog circuit by using an operational amplifier.

Please replace the paragraph at page 23, line 10, with the following rewritten paragraph:

Further, ~~When~~ when the periodic waveform generator outputs a square wave, a digital circuit can be used as the periodic waveform generator 1. For example, a 3-bit output port in a microprocessor or a digital signal processor is used. One bit in the output port is inverted periodically

by a software timer processing to generate periodic wave. If bit inversion is performed on the other two bits at timings shifted by predetermined times from the periodic wave, it is used as phase shifters. By controlling the 3-bit output port by a software program, correction in the two directions can be performed in a simple way.

Please replace the paragraph at page 24, line 11, with the following rewritten paragraph:

Fig. 12A shows a structure of a potential divider 16, Fig. 12B shows division into a plurality of regions of a liquid crystal element 18, and Fig. 12C shows phase difference of transmitting light in the liquid crystal element. The potential divider 16 has eight resistors of resistance value of R connected in series and resistors of resistance value of 4R added at two sides thereof. An output of a phase shifter (not shown) is connected to an end of the potential divider 16, and the output inverted by an inverting element 17 is connected to the other end thereof. From the potential divider, an output Va is outputted at the center thereof, and outputs Vb, Vc, Vd and Ve are sent from terminals arranged alternately towards the ends of the potential divider. As shown in Fig. 12B, the liquid crystal element 18 is divided into cylindrical regions, and elements 18a, 18b, 18c, 18d and 18e are arranged successively from the center. Electrodes 18a, 18b, 18c, 18d and 18e are connected to the outputs Va, Vb, Vc, Vd and Ve. Similarly to the liquid crystal element shown in Fig. 1, the liquid crystal element 18 has a common electrode, to which an output of the potential divider is connected.

Please replace the paragraph at page 30, line 14, with the following rewritten paragraph:

Next, a structure of the liquid crystal driver 32 is explained. Fig. 16 is a block diagram of an electrical circuit of the liquid crystal driver, wherein components represented with reference numerals 1 to 10 designate like or corresponding components shown in Figs. 1 to 10, and explanation thereon is omitted here. As shown in Fig. 15, the liquid crystal element 24 has electrodes 50 divided into a plurality of areas. An output V_{com} of the amplitude controller 2 is connected to the common electrode ~~24~~ 49 in the liquid crystal element 24.

Please replace the paragraph at page 30, line 24, with the following rewritten paragraph:

A lens shift correction controller 62 sends first and second change instructions 64 and 65 to first and second signal changers 60 and 61 according to lens shift instruction 35 of the lens shift quantity detector 41 (Fig. 15). The first signal changer 60 applies the output voltage Vb or Vc of the first potential divider 9 selectively to the electrode 50b in the liquid crystal element 24 according to the first change instruction 64 of the lens shift correction controller 62. In concrete, when the object lens is shifted to the ~~a~~ direction towards the internal circumference of the optical disk more than a predetermined distance, voltage Vb is applied selectively to the electrode 50b in the liquid crystal element 24, otherwise standard voltage Vc is applied selectively. The second signal changer 61 applies the output voltage Vd or Vc of the second potential divider 10 selectively to the electrode 50d in the liquid crystal element 24 according to the second change instruction 65. In concrete, when the object lens is shifted to the outer side of the optical disk more than a predetermined distance, voltage Vd is applied selectively to the electrode 50d in the liquid crystal element 24, otherwise standard voltage Vc is applied selectively.

Please replace the paragraph at page 32, line 23, with the following rewritten paragraph:

Fig. 19 shows the phase difference of transmitting light plotted against effective voltage applied to the liquid crystal element 24, wherein the phase difference of a light beam transmitting the liquid crystal element 24 is plotted against effective voltage applied to the liquid crystal element 24. When the effective voltage is small, the liquid crystal is not excited and the phase difference is small. As the effective voltage is increased, the phase difference tends to increase linearly. As the effective voltage is increased further, increase in the phase difference tends to become small. In the liquid crystal wherein the phase difference changes as mentioned above, the effective voltage of the electrode 50c is set in a range where the phase difference changes linearly, and it is set as an operating point (point R in Fig. 19) . The effective voltage is set by the amplitude controller 2.

Please replace the paragraph at page 38, line 24, with the following rewritten paragraph:

For example, ~~in~~ the liquid crystal pattern shown in Fig. 24A has first electrodes 70a, 70e, 70f and 70j, second electrodes 70b, 70b' and third electrodes 70d and 70d', and similar performance can be obtained. The electrodes 70b' and 70d' are provided around the center of liquid crystal pattern at both sides in radial direction relative to the center. The elongated electrode 70b is arranged at the outer circumference side of the electrode 70a to the right side relative to the center, while the electrode 70b' is arranged at the inner circumference side of the electrode 70e to the left side relative to the center. Similarly, the elongated electrode 70d is arranged at the outer circumference side of the electrode 70e to the left side relative to the center, while the electrode 70d' is arranged at the inner circumference side of the electrode 70a to the right side relative to the center.

Please replace the paragraph at page 42, line 1, with the following rewritten paragraph:

Further, in liquid crystal patterns shown in Figs. 26A and 26B, spherical aberration and astigmatic aberration are corrected while improving deterioration due to jitters when lens shift occurs. In the pattern shown in Fig. 26A, similarly to the pattern shown in Fig. ~~12A,~~ 12B, cylindrical electrodes are provided, and elongated narrow electrodes are arranged at the outer side of the cylindrical electrodes at the two side in radial direction. In the pattern shown in Fig. 26B, an outer cylindrical electrode is divided into eight areas along the circumference.